

8.0 ORBITER POST LANDING DEBRIS ASSESSMENT

After the 2:20 a.m. local/eastern time landing on 29 May 2000, a post landing inspection of OV-104 Atlantis was conducted at the Kennedy Space Center on SLF runway 15 and in Orbiter Processing Facility bay 3. This inspection was performed to identify debris impact damage and, if possible, debris sources.

The Orbiter TPS sustained a total of 113 hits, of which 27 had a major dimension of 1-inch or larger. This total does not include the numerous hits on the base heat shield attributed to SSME vibration/acoustics and exhaust plume recirculation (reference Figures 1-4).

The following table lists the STS-101 Orbiter debris damage hits by area:

	<u>HITS > 1-inch</u>	<u>TOTAL HITS</u>
Lower surface	19	70
Upper surface	0	0
Window Area	3	16
Right side	2	7
Left side	2	7
Right OMS Pod	0	4
Left OMS Pod	1	9
TOTALS	27	113

The Orbiter lower surface sustained 70 total hits, of which 19 had a major dimension of 1-inch or larger. Some of these damage sites (23 hits with 5 larger than 1-inch) were located in the area from the nose gear to the main landing gear wheel wells on both left and right chines, which is consistent with the loss of foam from the ET thrust panels. But the overall quantity and average size of the damage sites compared to previous flights were consequently reduced as a result of the pre-launch TPS venting modification. And some of the hits in this area may also be attributed to impacts from LO2 feedline bellows ice particles.

In general, the lower surface tile damage on this flight was considered to be a return to fleet averages, or "in family" (reference Figures 5-7). The comparative database will now reflect the mission set STS-70 through STS-85. These missions are significant because debris control measures had been optimized and debris damage sites on the Orbiter correspondingly minimized for each flight. Missions STS-86 through STS-103 are considered "out of family" due to the loss of TPS from External Tank thrust panels, a known debris source, and therefore outside the data base of random occurrences. With the incorporation of the successful – and full scale - TPS venting modification, missions flown after STS-103 will now be included in the database. Data from subsequent missions will be compared against the adjusted database and any data points outside the 3-sigma variation will be investigated as a new problem.

The largest lower surface tile damage site, located on the left wing immediately forward of the inboard elevon hinge, measured 8-inches long by 1.25-inches wide by 0.75-inches deep. The cause of this damage site has not been determined. However, it should be noted the damage site typically erodes during re-entry and may have initially been half the size listed above. Referencing the Debris Trajectory Database showed potential points of origin on the forward and mid segments of the left SRB, so it is possible a small, high density particle, such as a piece of cork or BTA may have come loose in flight.

Likewise, a lower surface tile (V070-191009-161) damage site on the right wing, approximately 10 feet forward of the right inboard elevon hinge, corresponded to the debris object impact detected in launch film E-224. The damage site measured 5.25-inches long by 1.5-inches wide by 0.5-inches deep, though re-entry erosion had enlarged this damage site as well. Due to the “gouge like” appearance and depth, this damage site was caused by a debris object with a greater density than ET foam, such as ice from the ET LO2 feedline bellows. Several tile hits aft of this location may have been the result of secondary impacts.

Again referencing the Debris Trajectory Database, Boeing analysts found 10 cases having impact locations closest to the actual impact location for the two Mach Numbers 0.60 and 1.05 closest to the actual flight Mach Number of 0.75. The majority of the closest cases corresponded to the density of ice (30-57 pcf). Therefore, the most likely source of the ice debris was the ET LO2 feedline upper bellows. The composition of the “vaporous streak” detected in the launch films was a mixture of ice debris and damaged tile material particles.

Numerous tile hits around the ET/ORB umbilicals were attributed to impacts from umbilical ice or shredded pieces of umbilical purge barrier material flapping in the airstream.

The main landing gear tires were reported to be in good condition for a landing on the KSC concrete runway. There was no ply under cutting on the main landing gear tires.

ET/Orbiter separation devices EO-1, EO-2, and EO-3 functioned normally. No ordnance fragments were found on the runway beneath the umbilicals. The EO-2 and EO-3 fitting retainer springs appeared to be in nominal configuration, though two of the EO-2 “salad bowl” clips were missing. No umbilical closeout foam or white RTV dam material adhered to the umbilical plate near the LH2 recirculation line disconnect.

Less than usual amounts of tile damage occurred on the base heat shield. All SSME Dome Heat Shield closeout blankets were in excellent condition.

No unusual tile damage occurred on the leading edges of the OMS pods and vertical stabilizer. Drag chute deployment caused a 2-inch long by 1-inch wide by 1/8-inch deep damage site on a stinger tile. On the inside edge of the upper right split rudder, a 3.5-inch by 1-inch piece of black tile surface coating material was missing and may have been the result of SSME ignition acoustics or vibration.

Damage sites on the window perimeter tiles was less than usual in quantity and size. Hazing and streaking of forward-facing Orbiter windows was moderate. An 8-inch long streak on window #2 led to a damage site in an upper right corner perimeter tile. The largest damage site, also located in window #2 perimeter tiles, was approximately 1.5-inches long by 0.75-inches wide. This damage may be attributed to impacts from FRCS thruster paper covers and RTV adhesive.

The post landing walkdown of Runway 15 was performed immediately after landing. No unexpected flight hardware was found. All components of the drag chute were recovered and appeared to have functioned normally. Both reefing line cutter pyrotechnic devices were expended.

In summary, the total number of Orbiter TPS debris hits, and the number of hits 1-inch or larger, were “in family”.

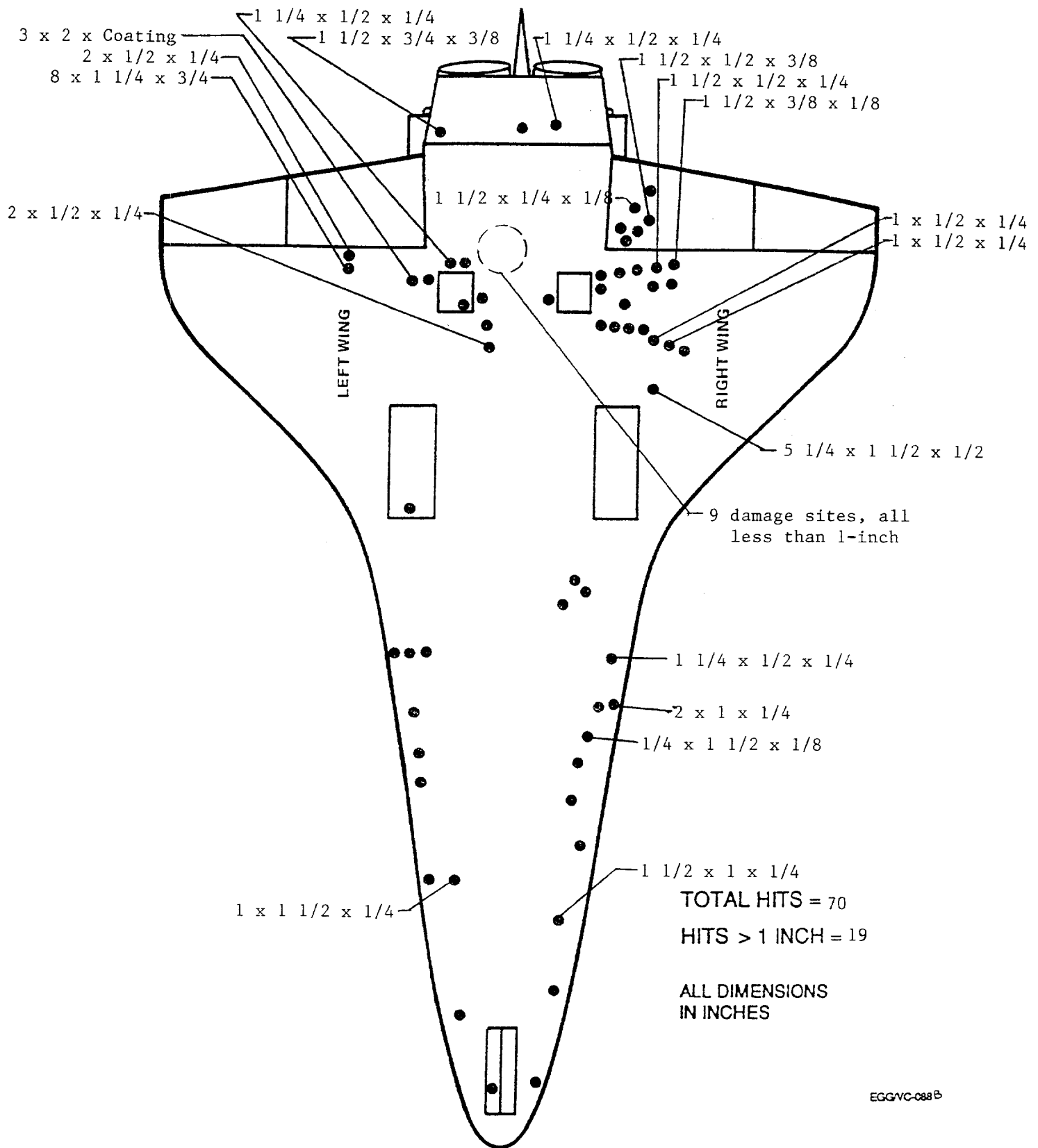


Figure 1: Orbiter Lower Surface Debris Damage Map

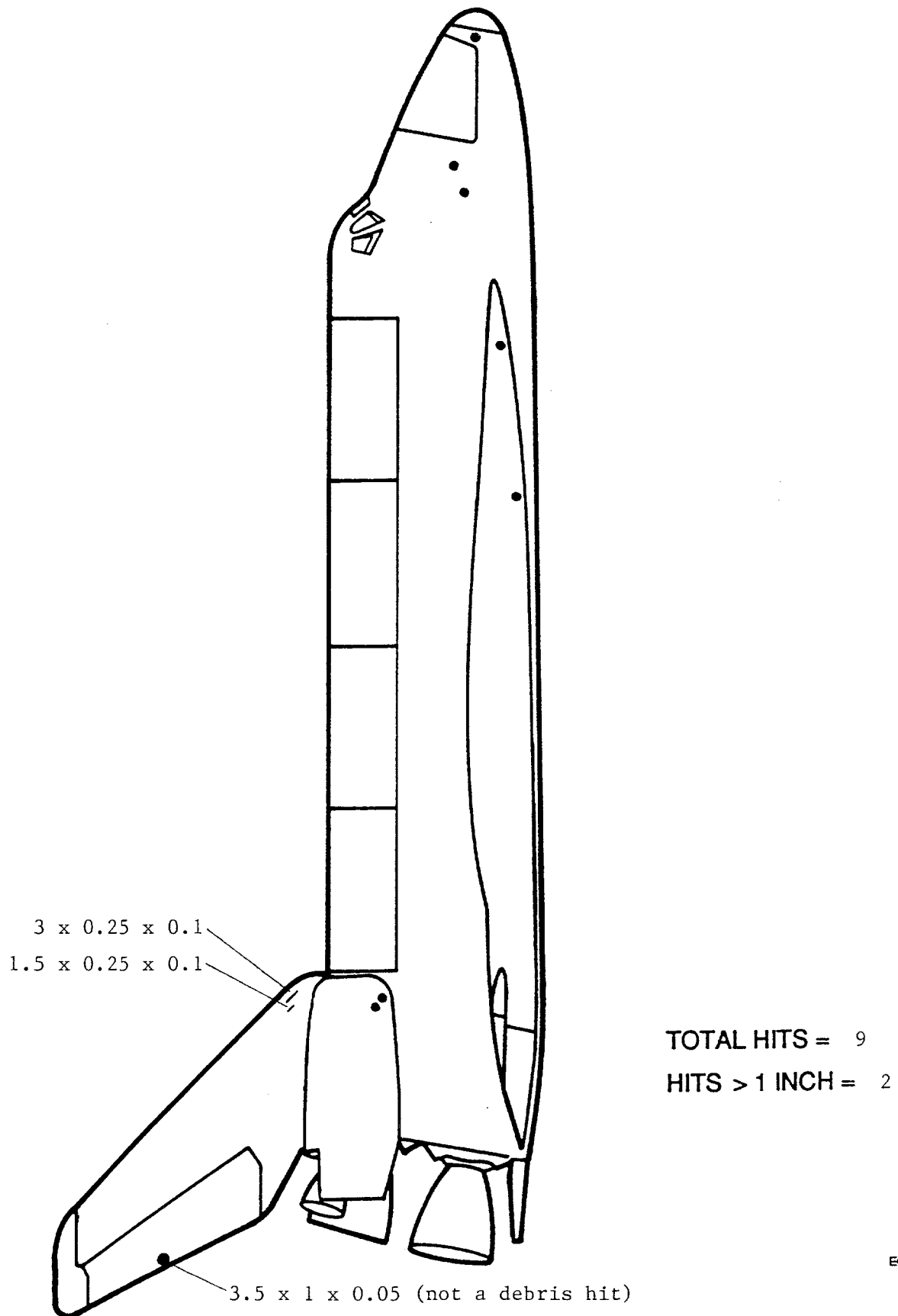


Figure 2: Orbiter Right Side Debris Damage Map

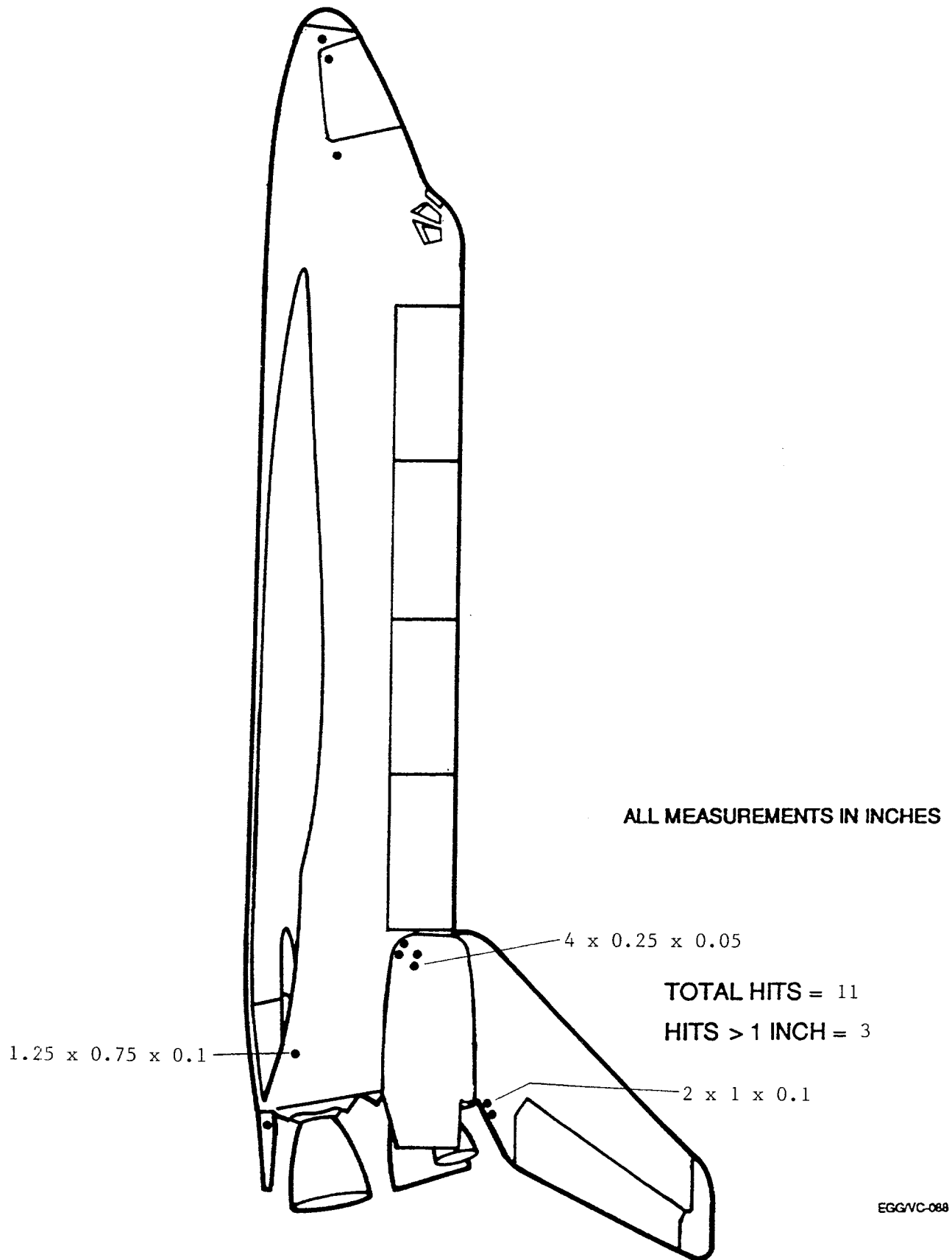


Figure 3: Orbiter Left Side Debris Damage Map

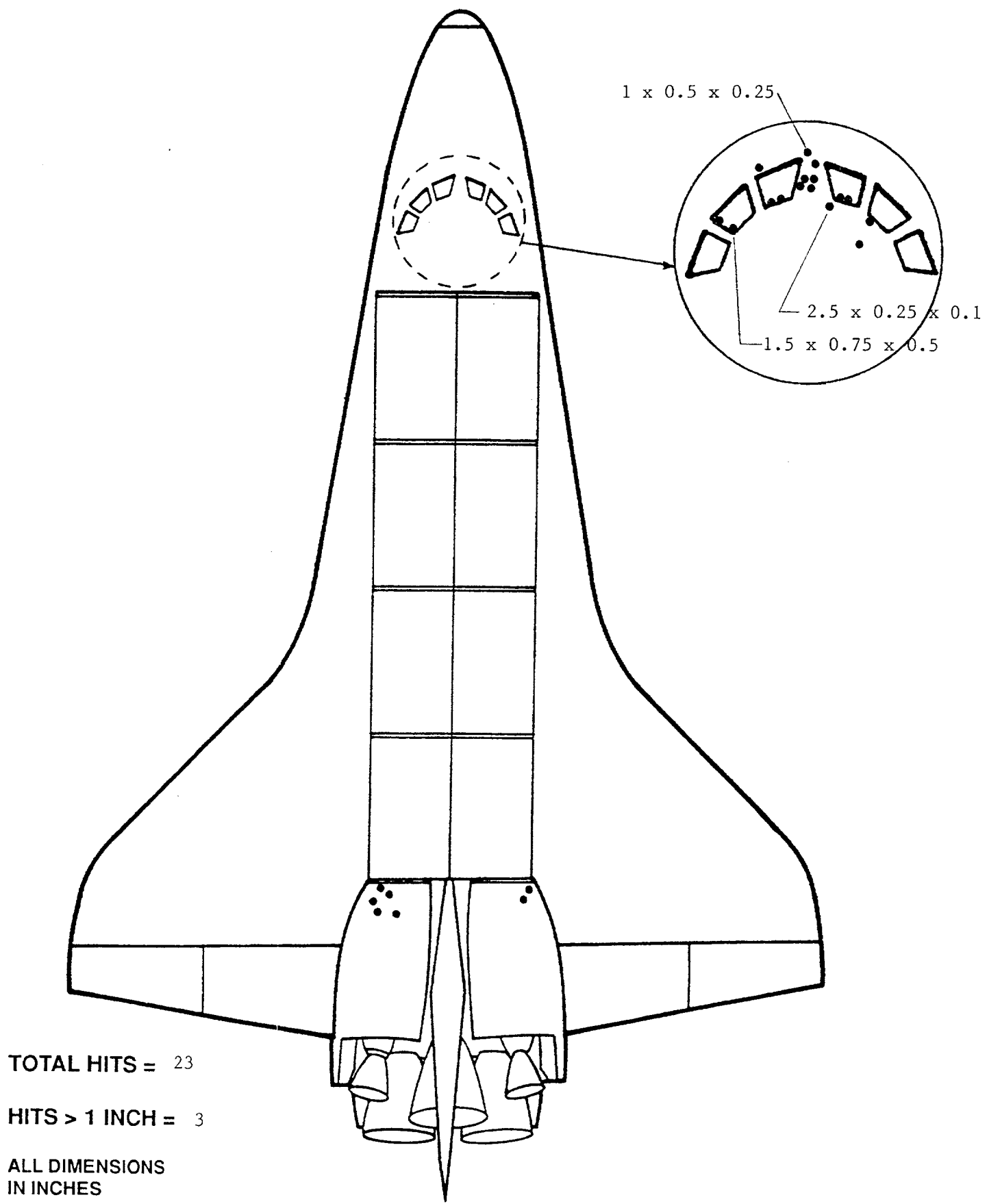


Figure 4: Orbiter Upper Surface Debris Damage Map

STS NUMBER	LOWER SURFACE		ENTIRE SURFACE	
	HITS > 1 INCH	TOTAL HITS	HITS > 1 INCH	TOTAL HITS
STS-70	5	81	9	127
STS-69	22	175	27	198
STS-73	17	102	26	147
STS-74	17	78	21	116
STS-72	3	23	6	55
STS-75	11	55	17	96
STS-76	5	32	15	69
STS-77	15	48	17	81
STS-78	5	35	12	85
STS-79	8	65	11	103
STS-80	4	34	8	93
STS-81	14	48	15	100
STS-82	14	53	18	103
STS-83	7	38	13	81
STS-84	10	67	13	103
STS-94	11	34	12	90
STS-85	6	37	13	102
STS-99	21	75	25	88
AVERAGE	10.8	60.0	15.4	102.1
SIGMA	5.9	35.6	6.1	31.6
STS-101	19	70	27	113

MISSIONS STS-86,87,89,90,91,95,88,96,93,103 ARE NOT INCLUDED SINCE THESE MISSIONS HAD SIGNIFICANT DAMAGE CAUSED BY KNOWN DEBRIS SOURCES

Figure 5: Orbiter Post Flight Debris Damage Summary

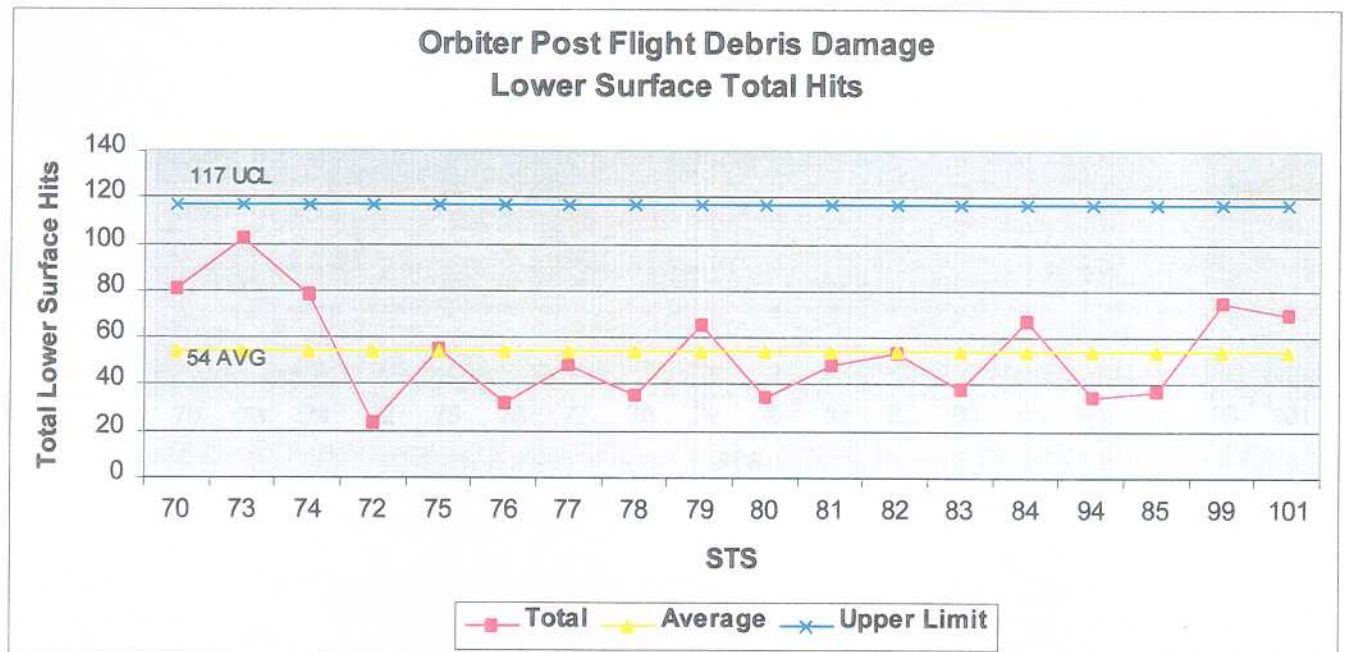
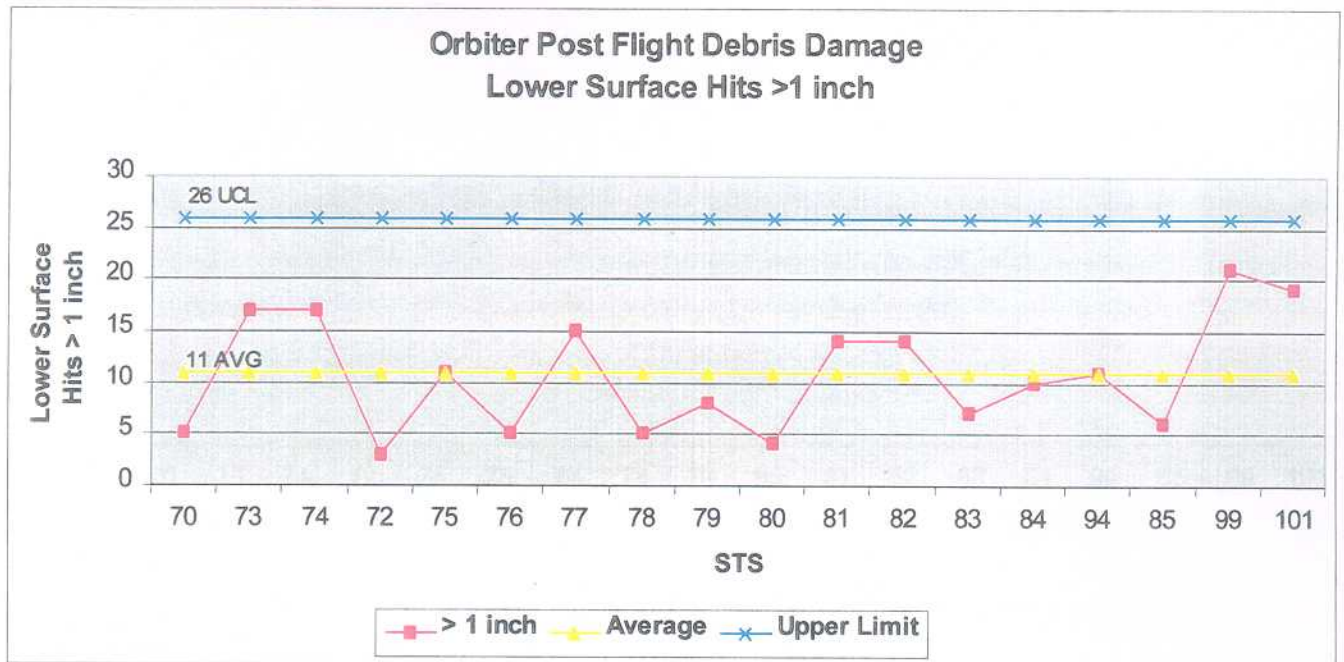


Figure 6: Control Limits for Lower Surface Hits

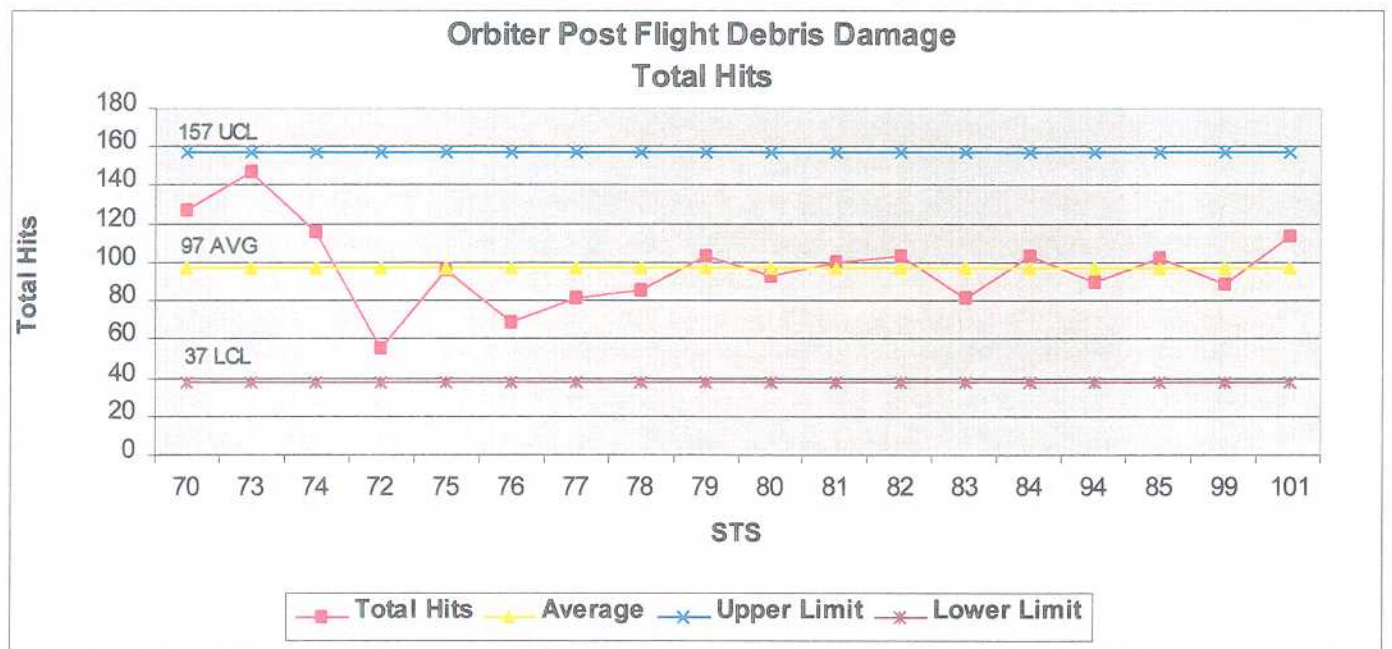
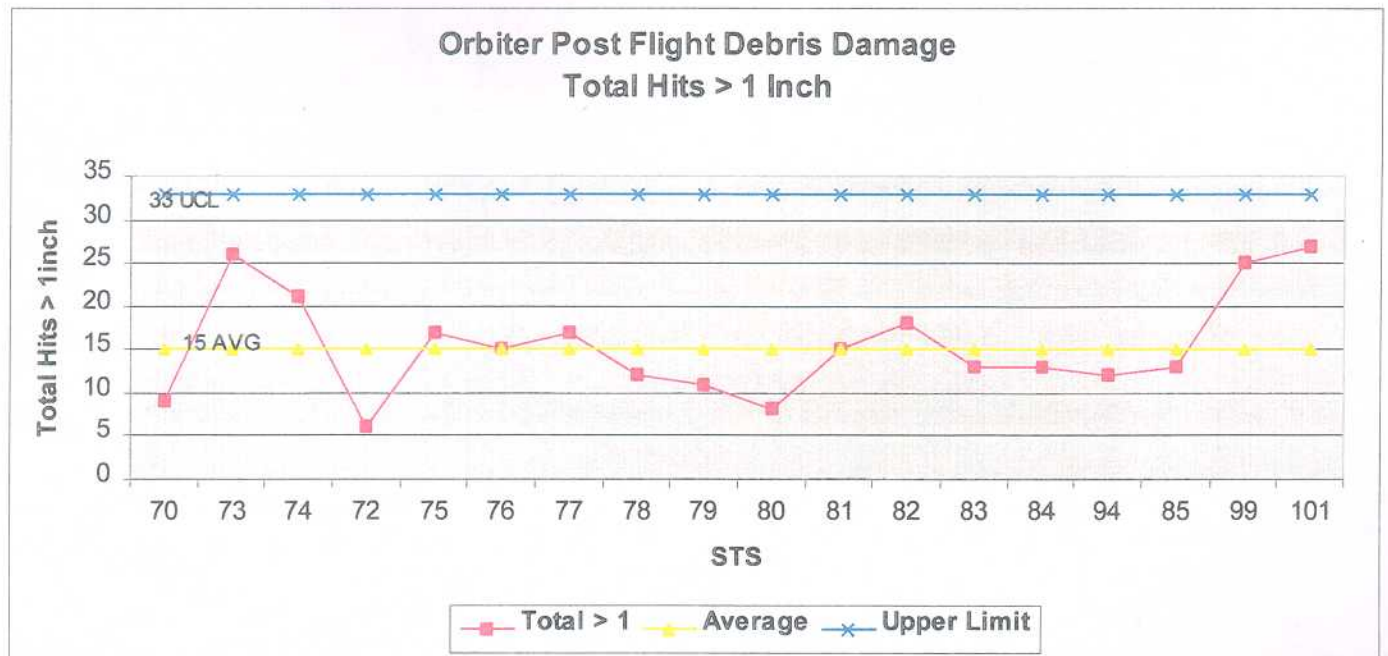


Figure 7: Control Limits for Total Hits



Photo 29: Overall View of Orbiter Sides

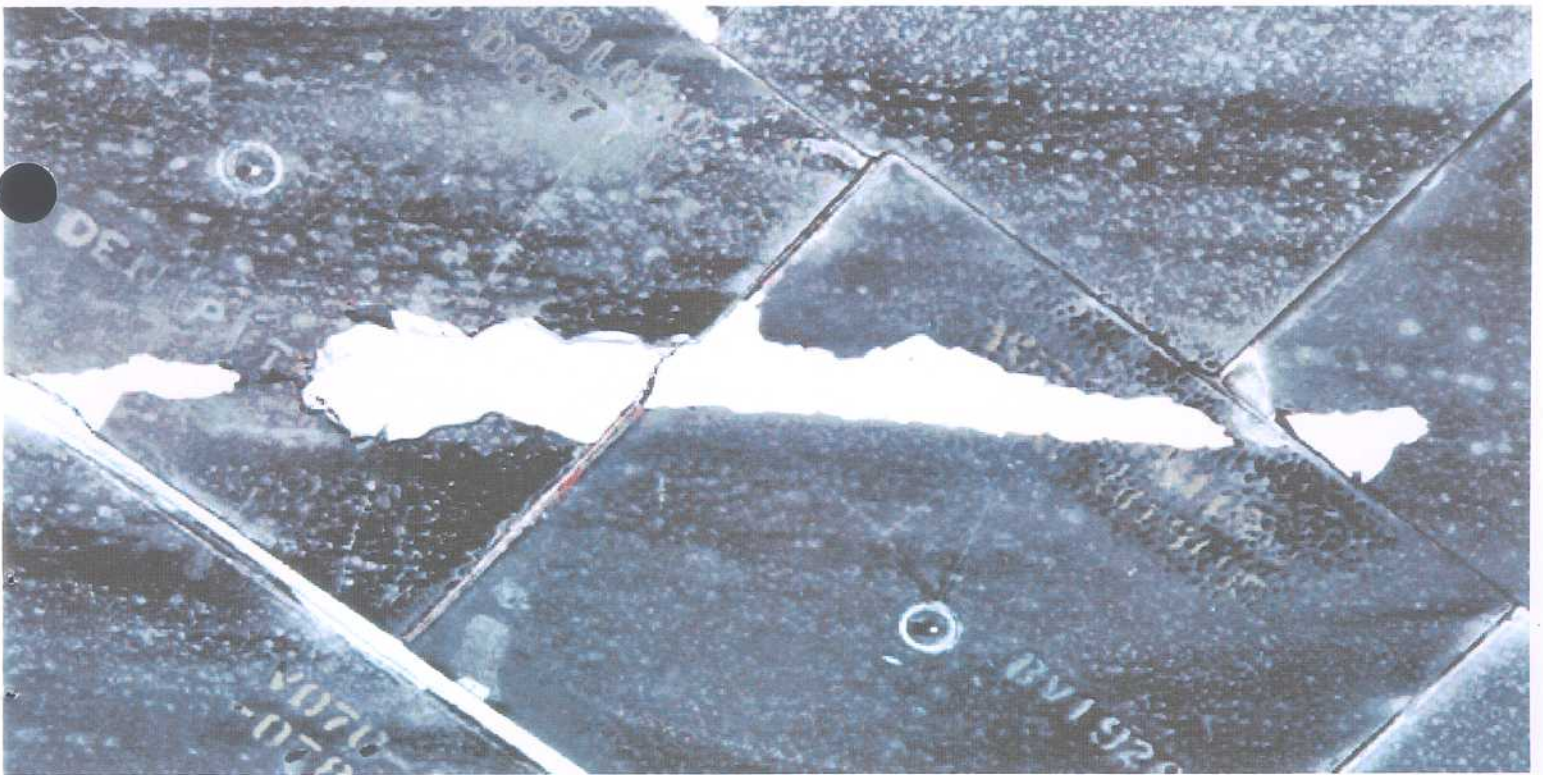


Photo 30: Damage to Lower Surface Tiles

Top photo shows a damage site on the lower surface of the right wing approx. 10 feet forward of the right inboard elevon hinge. This corresponded to the ice impact detected in launch films. The damage site measured 5.25-inches long by 1.5-inches wide by 0.5-inches deep, though re-entry erosion had enlarged this damage site. Bottom photo shows the largest lower surface tile damage site. It was located on the left wing immediately forward of the inboard elevon hinge and measured 8-inches long by 1.25-inches wide by 0.75-inches deep. The cause of this damage site has not been determined.

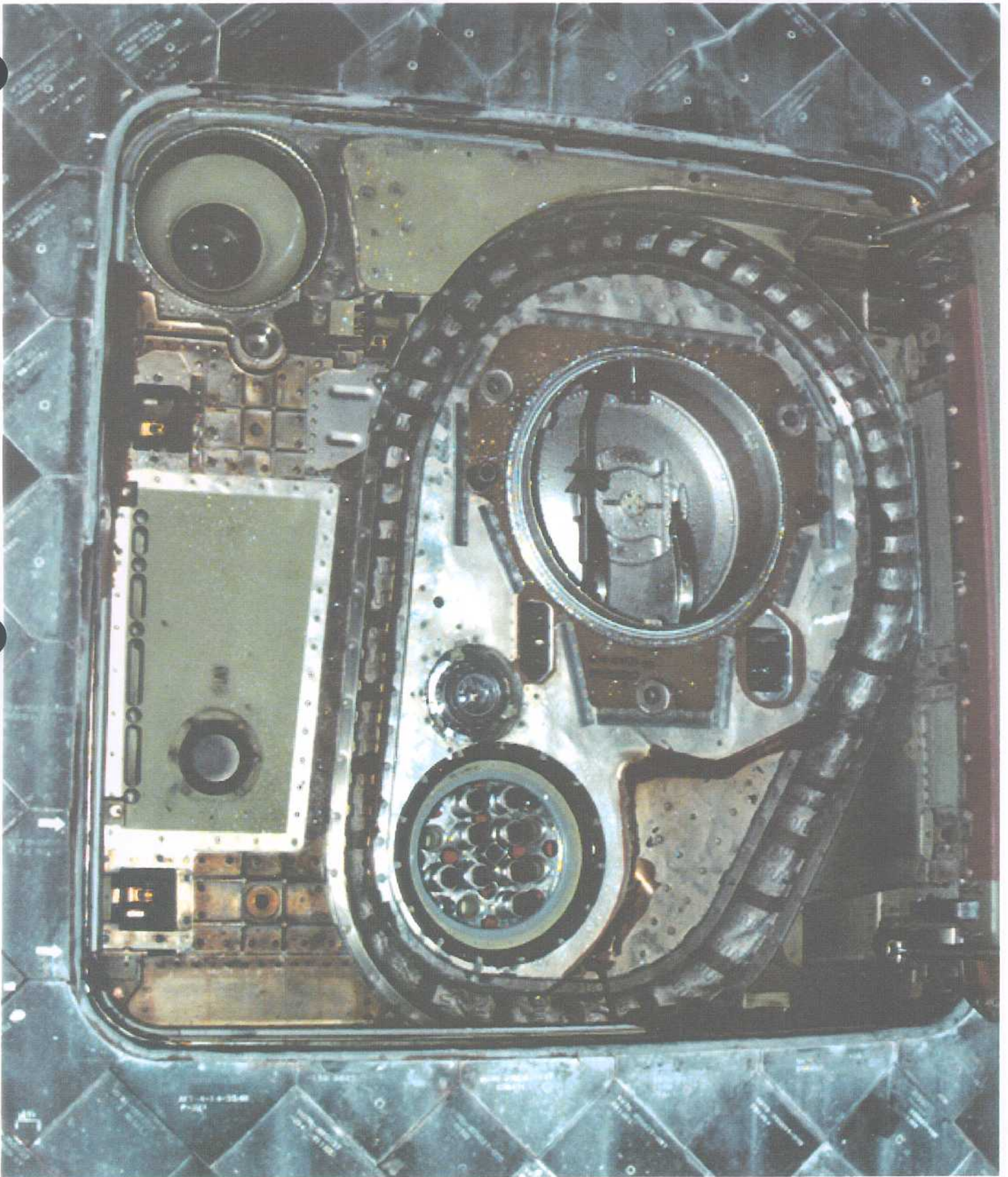


Photo 31: LO2 ET/ORB Umbilical

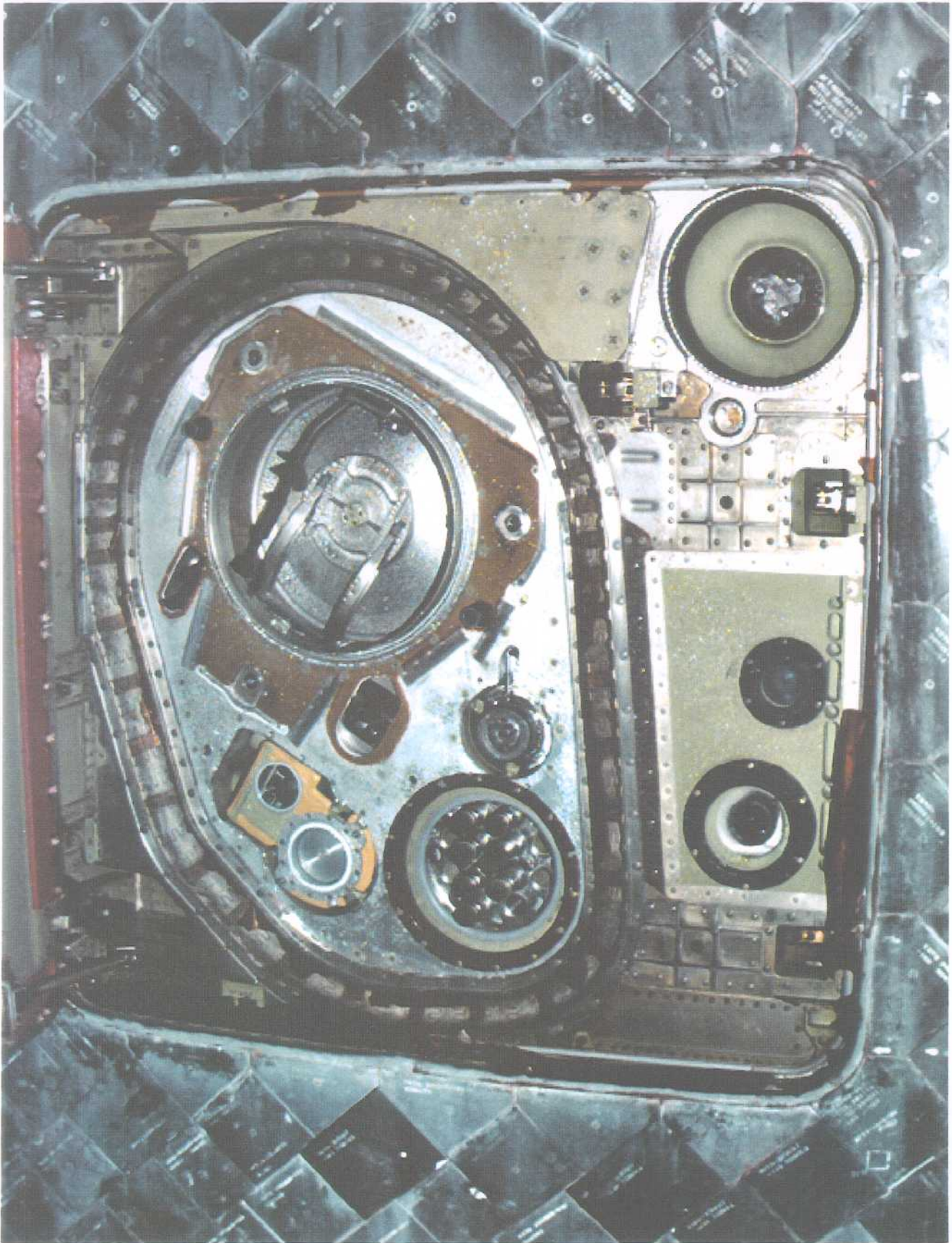


Photo 32: LH2 ET/ORB Umbilical

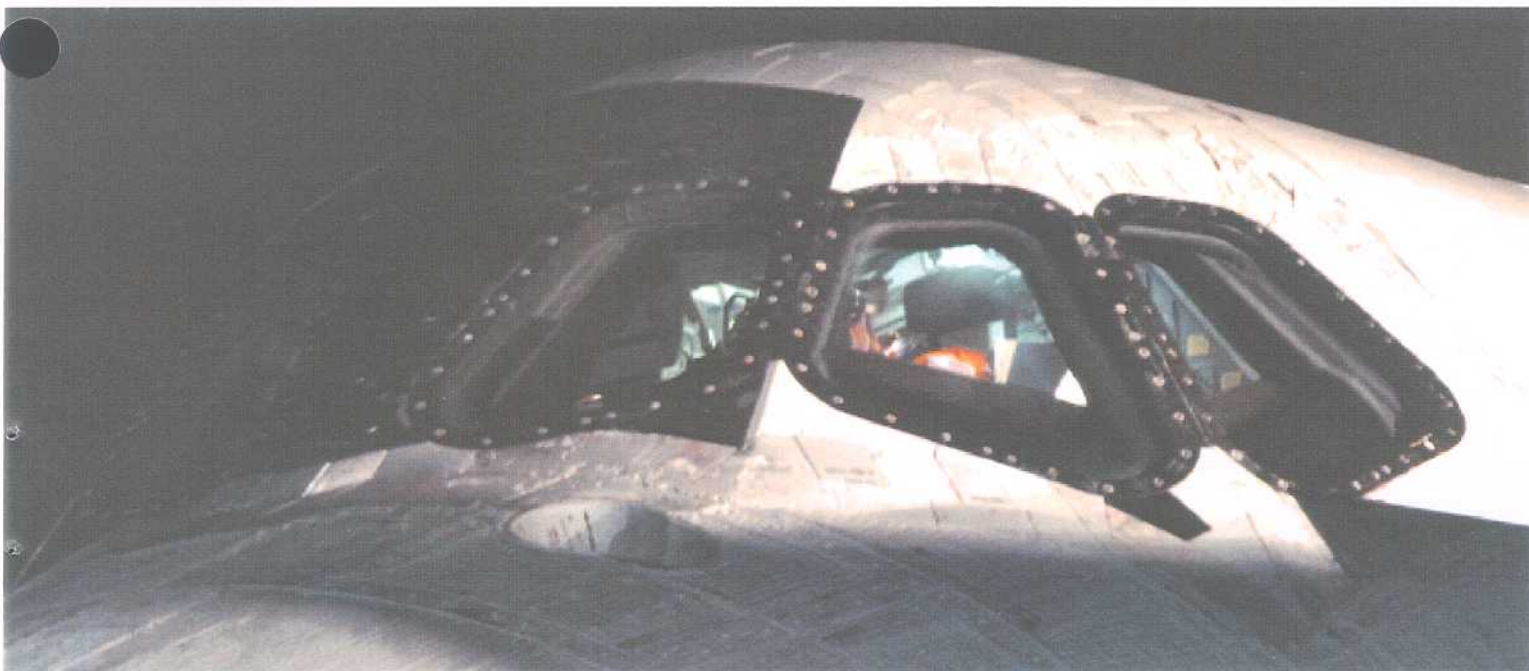
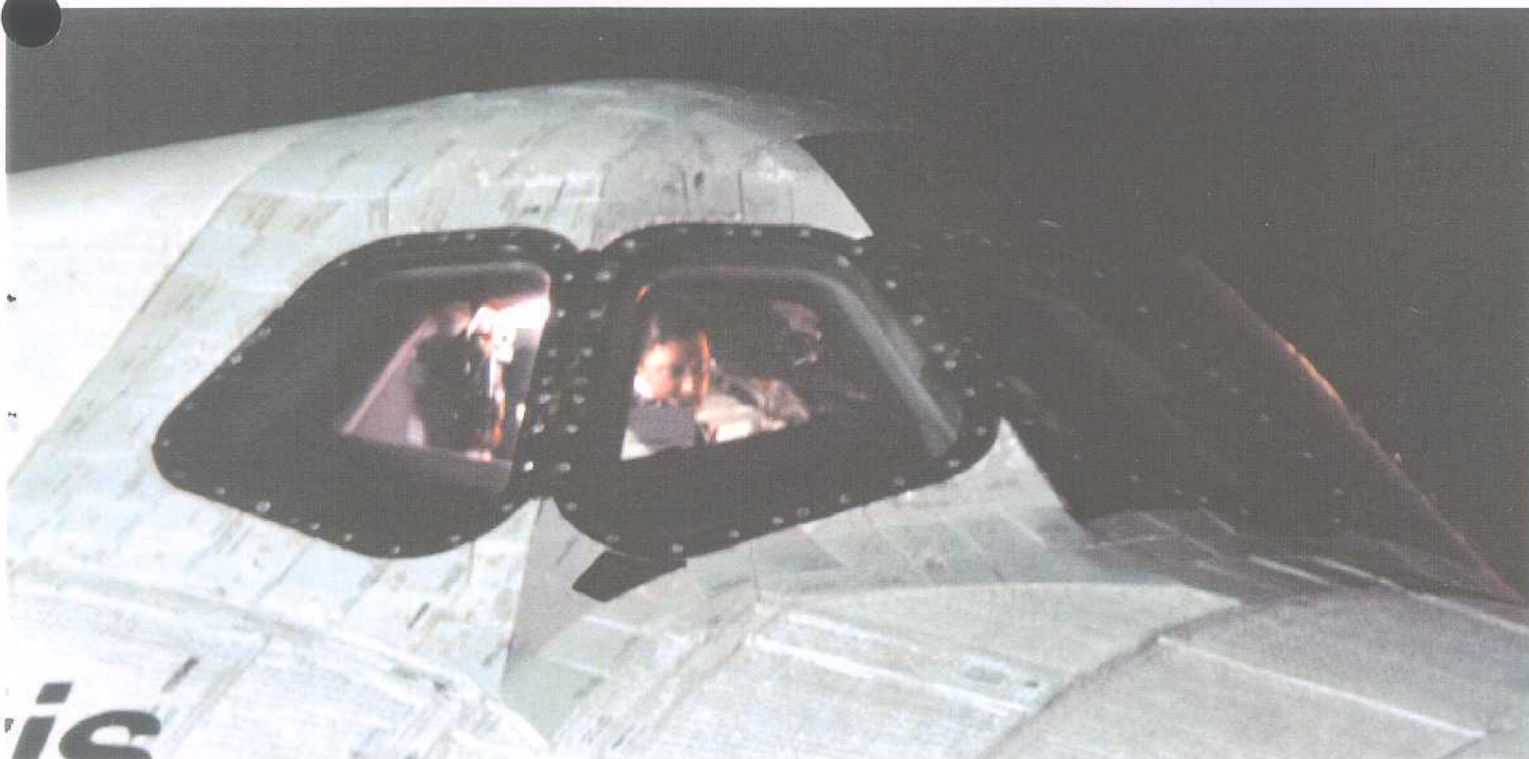


Photo 33: Windows

Damage sites on the window perimeter tiles was less than usual in quantity and size. Hazing and streaking of forward-facing Orbiter windows was moderate. The largest damage site, located in window #2 perimeter tiles, was approximately 1.5-inches long by 0.75-inches wide. This damage may be attributed to impacts from FRCS thruster paper covers and RTV adhesive.